TO A PROBLEM OF THE ANALISIS OF DIELECTRIC ROD ANTENNAS

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ABSTRACT.

A number of problems arising at designing and the analysis of dielectric rod antennas is reviewed. The complex propagation constants for the HE_{11} wave in a dielectric rod are obtained. The field disribution along the rod of finite length with allowance for reflections from the rod ends is analyzed.

INTRODUCTION

At present time decimeter and centimeter bands are widely used by different telecommunication systems. Requirements to antennas depend on their field of application. To protect antennas against climatic factors different covers are put on the open surfaces or the streamer is mounted, that can result in changes of an input resistance, distortion of antennas patterns, rereflections of a signal etc. The dielectric rod antennas, exciter of which is completely submerged in a dielectric rod from polystyrene or ceramics less depend on aggressive environmental factors and can be widely used by different telecommunication systems.

THE WAVE PROPAGATION ALONG THE ROD

The hybrid wave HE_{11} is the main wave of dielectric rod of circular cross section. It has both magnetic and electrical longitudinal components of an electromagnetic field. From a condition of continuity the tangent components on a surface of a rod it is possible to receive the following equation:

$$4\cdot\pi^2\cdot f^2\cdot g^2\cdot n^2\cdot(\varepsilon-1)^2/c^2=[\varepsilon\cdot\psi_2^2\cdot(\frac{\psi_1\cdot J_{n-1}(\psi_1)}{R\cdot J_n(\psi_1)}-\frac{n}{R})-\psi_1^2\cdot(\frac{\psi_2\cdot K_{n-1}(\psi_2)}{R\cdot K_n(\psi_2)}-\frac{n}{R})]*$$

$$*[\psi_2^2\cdot(\frac{\psi_1\cdot J_{n-1}(\psi_1)}{R\cdot J_n(\psi_1)}-\frac{n}{R})-\psi_1^2\cdot(\frac{\psi_2\cdot K_{n-1}(\psi_2)}{R\cdot K_n(\psi_2)}-\frac{n}{R})];$$

Where: $\psi_1^2=\frac{4\cdot\pi^2\cdot f^2\cdot\varepsilon\cdot R^2}{c^2}-g^2=(\chi_1\cdot R)^2$, χ_1 transversal wave number in a rod,

$\psi_2^2=\frac{4\cdot\pi^2\cdot f^2\cdot R^2}{c^2}-g^2=(\chi_2\cdot R)^2$, χ_2 transversal wave number outside of a rod, $g=hR=\mathrm{Re}(g)-i\cdot\mathrm{Im}(g)$, h is a longitudinal wave number.

Numerical solution of the given transcendental equation rather g at known f,R,ε,n allows to find required propagation coefficients of an interesting type of wave.

The obtained results for two materials are shown in the fig.1

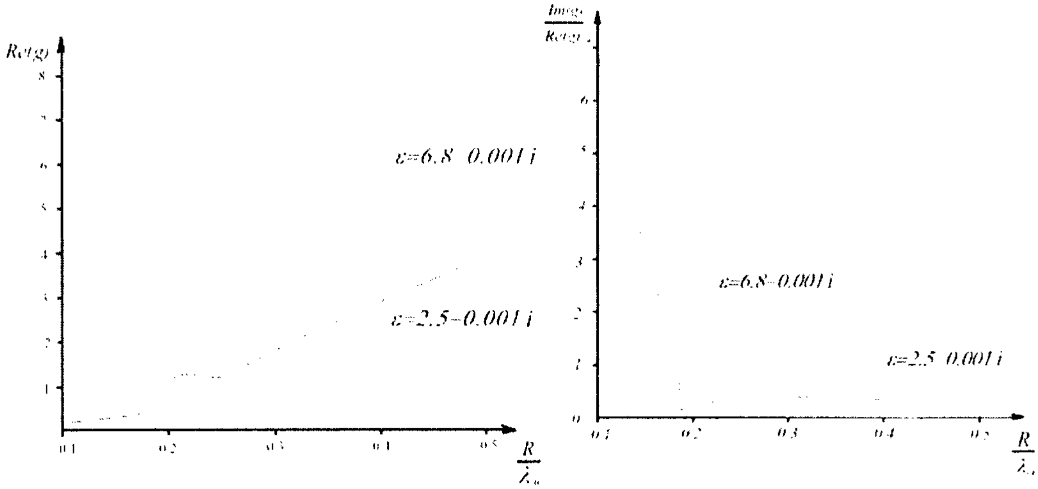
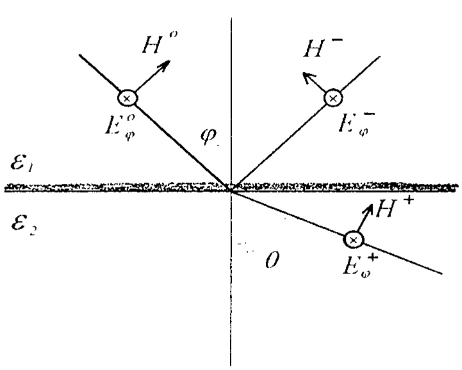


Fig.1. The HE_{11} longitudinal wave numbers

REFLECTION FROM THE ROD END

As the first approach the hybrid wave reflection from the rod end can be considered as the sum of reflections of different polarization inhomogeneous waves.[1]



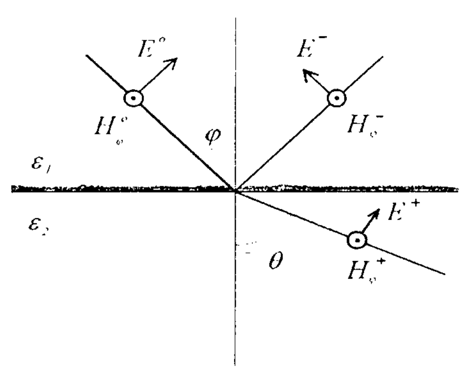
$$R_1 = \frac{W_2 \cos\varphi - W_1 \cos\theta}{W_2 \cos\varphi + W_1 \cos\theta}$$

$$W_1 = \frac{E_\varphi^0}{\sqrt{(H_r^0)^2 + (H_z^0)^2}} \qquad \cos\theta = \pm\sqrt{1-\sin^2\theta}$$

$$\cos\varphi = \frac{H_r^0}{\pm\sqrt{(H_r^0)^2 + (H_z^0)^2}}$$

$$W_2 = \frac{E_\varphi^+}{H^+} = \frac{E_\varphi^0 \cdot \sin\theta}{H_z^0}$$

$$\sin\theta = \sqrt{\varepsilon_1} \cdot \frac{H_z^0}{\sqrt{(H_r^0)^2 + (H_z^0)^2}}$$



$$R_2 = \frac{W_1 \cos\varphi - W_2 \cos\theta}{W_1 \cos\varphi + W_2 \cos\theta}$$

$$W_1 \cos\varphi = \frac{E_r^0}{H_\varphi^0}$$

$$W_2 \cos\theta = \frac{E_r^+}{H_\varphi^+} = \frac{\varepsilon_1 E_z^0 ctg\theta}{H_\varphi^0}$$

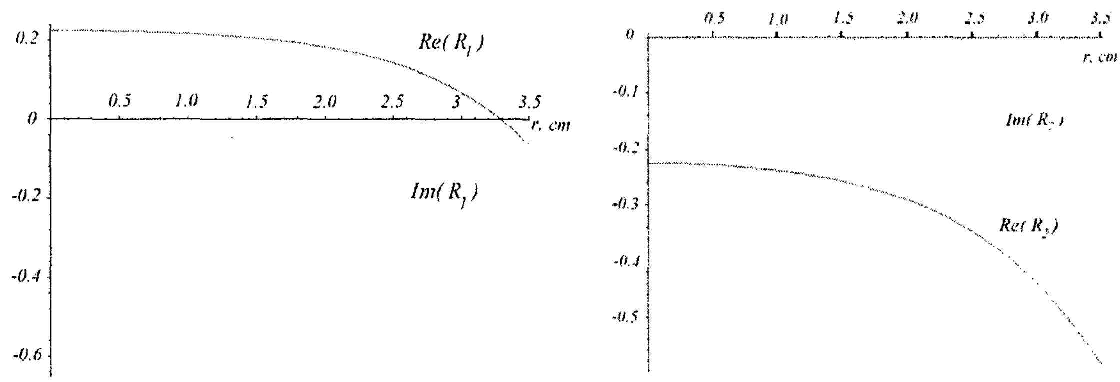
$$ctg\theta = \frac{\cos\theta}{\sin\theta} = \frac{\pm\sqrt{1-\sin^2\theta}}{\sin\theta}$$

$$\sin\theta = \sqrt{\varepsilon_1} \cdot \sin\varphi = \sqrt{\varepsilon_1} \cdot \frac{E_z^0}{\pm\sqrt{(E_z^0)^2 + (E_r^0)^2}}$$

When the square radix sign is chosen, it is necessary to take in to account that $abs(R_{1,2}) \le 1$

The obtained results for the reflection coefficients depend on distance from the rod axis. The antennas pattern calculation uses the rod surface field distribution, that's why the reflection coefficient values when $r = R$ are used mostly.

Thus for $\varepsilon = 2.5 - 0.001i$, $f = 2.5GHz$, $R = 3.5cm$ following results were obtained:



$R_1\big|_{r=R} = -0.064 - 0.637i$ $\qquad$ $R_2\big|_{r=R} = -0.587 - 0.317i$

Fig. 2. The reflection coefficients for the different polarizations

Usually one end of the rod is leaned against waveguide metal wall. In this case the reflection coefficient is equal -1 or +1 (depend on polarization of the falling wave). Thus for the components E_φ, H_r, H_z the reflection coefficient from first (metallized) end is equal $R_0 = -1$ from the second end (in free space) is equal R_1. For the components H_φ, E_r, E_z the reflection coefficient from the first end is equal $R_0 = 1$, from the second one is equal R_2.

The field distribution along the rod of the finite length L can be obtained as superposition of multiply wave reflections from the rod ends. In the general case the each component distribution along the rod can be presented as

$$U(\alpha, z) = U_0(\alpha) \cdot e^{-ihz+\phi_0} \cdot \frac{1 + R_{1,2} \cdot e^{-2ih(L-z)}}{1 - R_0 \cdot R_{1,2} \cdot e^{-2ihL}}$$

where h is a longitudinal wave number, ϕ_0 is an initial phase, $U_0(\alpha)$ is the angle component distribution (variety $\sin(\alpha)$ *or* $\cos(\alpha)$).

REFERENSES

[1] V.V. Nicolskiy. Theory of electromagnetic field. Moskow: Vis. Shkola, 1961. (in Russian)